



Title of Investigation:

Passively Q-switched, High Average Power, Single-Frequency Monolithic Nd:YAG Ring Laser

Principal Investigator:

Dr. Steven X. Li (Code 554)

Other In-house Members of Team:

Dr. Anne-Marie Novo-Gradac (Code 554)

Other External Collaborators:

None

Initiation Year:

FY 2005

Aggregate Amount of Funding Authorized in FY 2005 and Earlier Years:

\$58,000

Funding Authorized for FY 2005:

\$58,000

Actual or Expected Expenditure of FY 2005 Funding:

In-house: \$20,000; Mechanical Design, \$15,000; Fiber-Coupled Laser Diodes, \$7,200; Laser-Diode Bars, \$2,000; Laser-Diode Driver, \$7,800; Laser Crystal, \$4,000; Q-switch, \$2,000

Status of Investigation at End of FY 2005:

Transition to NASA Laser Risk Reduction Program; to be continued through 2006.

Expected Completion Date:

September 2006

DDF annual report

Purpose of Investigation:

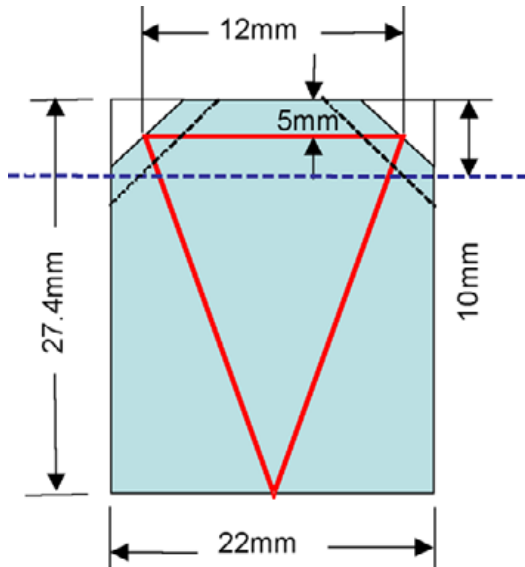
Today, wind is the main process shaping the Martian surface. Astronomers suspected wind even before spacecraft explored the surface. They observed changes in the brightness of the planet over time and suspected that wind-borne dust clouded the atmosphere. The presence of winds was overwhelmingly confirmed when Mariner 9 arrived at Mars in the middle of a huge dust storm. Wind lidar, a laser-based Doppler remote-sensing technique, is the most viable method to measure the wind profile near the Martian surface. By measuring the laser frequency shift from the backscattered photons off the aerosols, we can precisely determine the motion of the aerosol particles and winds. One of the key components of the wind-lidar system is the very stable, high-peak power, single-frequency laser source. The purpose of this investigation is to develop a highly reliable switch to turn the laser on suddenly to send laser pulses. The innovation is to do this “passively” — no moving parts, no electronics. The method is to switch on and off by having the laser cavity filled with a material that absorbs the laser light if its intensity is below a critical value, and is transparent to it if the intensity is above that value. In technical terms, the material switches the cavity from low Q (high absorption) to high Q (low absorption). The goal of this investigation is to develop a high average power, passively Q-switched, single longitudinal mode, monolithic Nd:YAG laser for space-based remote sensing applications.

This type of laser would be an excellent candidate for Doppler wind measurement, which requires single-longitudinal mode operation. Currently, stable single frequency lasers are all operated in cw mode. To achieve a single-frequency, high-peak, power-pulsed laser operation, a low-power cw laser is injection seeded to the pulsed slave laser. However, there are three major drawbacks for applying that technique to space-based lasers. First, it will require an additional cw single-mode laser. Second, the seed laser must be carefully aligned to the slave laser and it must maintain a tight and proper cavity lock. This requires additional electronic circuitry. Third, the slave laser must be actively Q-switched, which requires even more circuitry and the use of high voltage. The failure of any of these additional systems could result in complete loss of a mission.

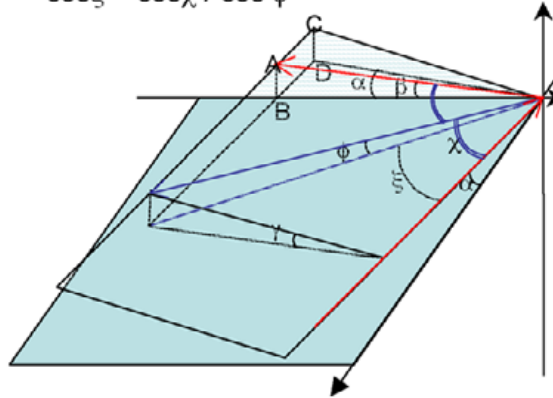
Our laser design is based on highly reliable monolithic non-planar ring oscillator (NPRO) architecture. The laser is side pumped through the top crystal surface, which allows us to use conduct cooled, high power laser diodes. A cavity round-trip path is formed by reflection at the dielectrically coated front surface and by three total internal reflections at the two tilted side surfaces and at the top surface. A saturated absorber (Cr^{4+} :YAG) is optically bounded to the end of the Nd:YAG crystal to achieve a passive Q-switch operation.

Accomplishments to Date:

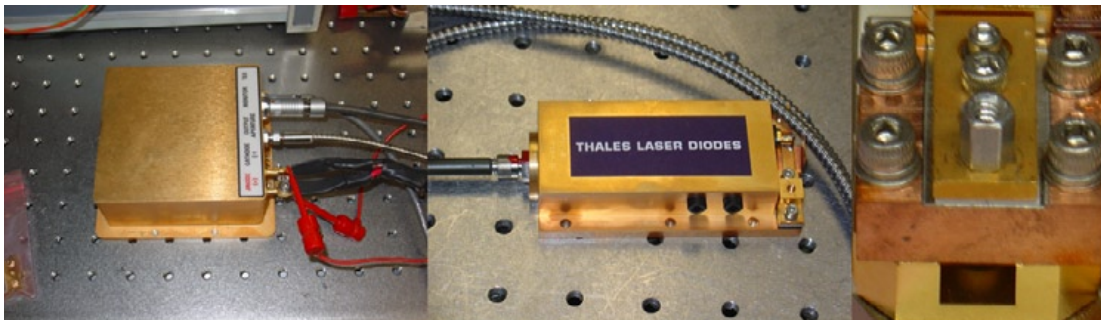
Our first accomplishment was designing a non-planar ring oscillator laser slab. We have derived a general formula to calculate the crystal cut angle to form a NPRO. Zemax optical- ray tracing software also has verified the design. Our slab design makes side pumping possible through the top of the crystal. The YAG crystal is about 10 mm x 12 mm x 2 mm and is doped at 1.1 percent Nd. A curved output coupler will be used to form a ring cavity. For the pulsed operation, a passive Q-switch (Cr^{4+} :YAG) will be inserted into the cavity.



$$\begin{aligned} \tan \gamma &= \tan \beta / \cos \alpha \\ (\sin 2\chi)^2 &= 1 - (\cos \beta * \sin \alpha)^2 \\ \sin \phi &= \sin \chi * \sin \gamma \\ \cos \xi &= \cos \chi / \cos \phi \end{aligned}$$



We also have received and tested two fiber-coupled laser diodes and two CS-packaged diode bars. These diodes output more than 20 W of optical power at 808 nm.



Planned Future Work:

We have not yet received the laser crystal. We are scheduled to complete final fabrication of the laser slab in mid-2006. The slab will be bonded onto a liquid-cooled heat sink. By June 2006, we plan to achieve the cw laser operation.

Key Points Summary:

Project's innovative features: To our knowledge, this is the first attempt to achieve a short laser pulse, high-peak power, without an active feedback controlled single-frequency laser. By combining the side pump, passive q-switched and NPRO feather, it is possible to design an innovative laser for a remote wind-sensor application.

Potential payoff to Goddard/NASA: A compact, lightweight, single-frequency laser is the key component for a space-based wind lidar. The successful development of such a laser source will greatly increase the technique readiness for the future Mars exploration missions.

The criteria for success: The activity's main criterion for success would be the successful operation of the side-pumped ring laser, with stable single-longitudinal mode.

Technical risk factors: This is the first attempt to achieve a non-active feedback q-switched stable single frequency laser. We attempt to do it by combining two techniques. This entails substantial risk for quick success.